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LETTER

Nature connection, experience and policy encourage and maintain adaptation to drought in urban agriculture

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Abstract

Climate change is challenging the sustained delivery of ecosystem services from urban agriculture. Extreme, prolonged drought in combination with high heat events affect urban crop production due to limited water availability and affect environmental management and adaptation to environmental conditions. In this study, we use urban community gardens in central coast California as a system to investigate how people are adapting their management behaviors over three time periods—before, during and after the longest drought in California's recent history. We specifically ask how behavioral change is impacted by water policies and gardener characteristics (including gardening experience, formal education, drought concern, and relationship to nature). Through structural equation modeling and multivariate analyses, we show that nature relatedness and gardening experience impact drought concern which in turn impact behavioral change, and potentially gardener's ability to sustainably manage water and to adapt to drought conditions. Planting motivations are also important, influencing people's adoption and retention of practices over time. Yet where concern may be absent, water policies are able to promote and maintain behavioral change and conservation-based practice adoption. Thus, environmental awareness and experience in combination with policies are needed to promote and support proactive behavioral change and adaptation to create resilient urban food production systems under climate change.

1. Introduction

Urban agriculture supports urban food systems and provides important urban ecosystem services (Barthel *et al* 2015, Lin *et al* 2015, Wiskerke 2015). Yet urban agriculture is increasingly vulnerable to environmental change impacting cities, including more frequent and intense drought and heat (Wortman and Lovell 2013, Lin and Egerer 2020). Such seasonal patterns of weather extremes linked to climate change are reducing access to—while increasing the demand for—water inputs in urban agriculture (Milly *et al* 2008, Hunt *et al* 2013). Limited water availability and access challenge plant maintenance by restricting water available to already heat and water stressed plants. These environmental impacts could reduce the sustainability of urban agriculture by negatively affecting crop production (Tardieu *et al* 2000) and natural resource conservation (Eriksen-Hamel and Danso 2010).

Climate change adaptation through adoption of conservation-based practices is therefore imperative to improve water use sustainability in changing climates and during times of water shortages and drought. Urban gardeners have a range of options from reducing water use to adopting drought hardy plants and crop varieties,

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adopting new soil management techniques including mulching, or employing other technologies to make water use more sustainable. For example, urban agriculture research encourages composting, cover cropping, and straw mulching to improve soil fertility and water holding capacity (Beniston and Lal 2012) because ground cover and soil management practices can reduce soil moisture loss rates (de Pascale *et al* 2011, Lin *et al* 2018). Gardeners have already adopted water-saving ground cover and soil amendment practices, both in times of drought and not, which should improve soil moisture conservation (Gregory *et al* 2015).

Changes in environmental management behavior are especially complex to understand, predict, and direct (Ives and Kendal 2014). Interactions among environmental conditions, governance systems, and human behavior together shape environmental management decisions (Lin and Egerer 2020). Environmental policies or water regulation rules, such as those that are often implemented during droughts, can lead to water restrictions in agriculture, thus affecting watering patterns or planting decisions (White *et al* 2007, Lempert and Groves 2010). Although water restrictions may change behavior, these behavioral changes can depend on a number of other factors besides current conditions, such as historical water use and availability, and technical capacities (Yazdanpanah *et al* 2014). Predictors of behavior change also include people's perceptions and awareness of environmental conditions and their environmental attitudes (e.g. around climate change), and especially values informed by their life-long social-environmental experiences (López-Marrero and Yarnal 2010, Kuruppu and Liverman 2011). Specifically, education and concern about current problems and people's relationship with nature can all inform management and adaptive capacity to change (Fazey *et al* 2007,Wamsler *et al* 2012). For example, in arid regions where water is scarce, farmers' perceptions of risk influence both intention to conserve water and water conservation behavior in the absence of government regulation (Yazdanpanah *et al* 2014). In addition, social norms instilled around water conservation strongly influence farmers to adopt water management strategies.

Increased outdoor nature exposure, experience with natural processes, and nature connection is also related to cognitive awareness of human-nature interdependencies (Giusti *et al* 2014), greater emotional connection to nature, and heightened environmental concern (Mayer and Frantz 2004, Dutcher *et al* 2007, Wang *et al* 2019). In suburban households in the Mediterranean coast, domestic water use behaviors depend on residents' characteristics including the length of residency and education (Garcia *et al* 2013). In community-based urban agriculture, past experience and knowledge exchange among people promotes adaptation to climate conditions, ultimately building resilience and urban agriculture sustainability (Westley *et al* 2013, Schultz *et al* 2015). Experimentation, behavioral adaptation, and co-learning in management prepares gardeners for current and future disturbances and therefore their ability to adapt to, for example, water scarcity and climate change (Krasny and Tidball 2009, Barthel *et al* 2010, 2015). If and how urban gardeners have changed their management behaviors over time in response to climate change events is an indication of adaptive decision making.

This paper examines behavioral change around watering and adopting water saving measures using urban community gardens in the California Central Coast region as a case study. California recently experienced an unprecedented climate-change induced drought with both extreme dry and hot years (Diffenbaugh *et al* 2015 Mann and Gleick 2015). The drought significantly affected water availability and generated concern about drought impacts and new policies on water use in urban agriculture in the region (Diekmann *et al* 2017). We studied urban gardener management behaviors as an indication of climate change adaptation by looking at reported practices used at three time periods—before, during, and after the drought. Specifically, we examine if and how changes in practices are related to garden water policy or gardener characteristics including concerns around drought, gardening experience, education, motivations to garden, and their relationship to nature. We ask: (1) what gardener characteristics and garden policies influence gardener management practices?; and (2) what are the changes in practices during drought and after drought in relation to gardening characteristics and garden policy?

2. Methods

2.1. Study system

We used the California Central Coast region as a model system, spanning two dominant ecoregions in which people live, including the Lower Santa Clara Valley and the Monterey Bay Plains (Monterey, Santa Clara and Santa Cruz Counties) (Egerer *et al* 2019a, Lin and Egerer 2020). The Lower Santa Clara Valley is characterized by alluvial plains, xeric soil moisture regimes, thermic soil temperatures, and a Mediterranean climate. Mean annual rainfall is 300–400 mm, and daily mean temperature ranges 9 °C–20 °C. The landscape's vegetation was historically characterized by coast live oak trees, California oatgrass, and needlegrass grasslands. Today, the dominant land use is urban and residential. The Monterey Bay Plains is characterized by alluvial plains and terraces, xeric soil moisture regimes, isomesic soil temperatures, and a marine-influenced climate including heavy summer fog. Mean rainfall ranges 700–800 mm (2–155 mm per month), and daily mean temperature ranges 9 °C–17 °C. The natural vegetation includes coast live oak, California oatgrass, and coastal shrub. Today, the long frost-free period supports extensive industrial cropland agricultural land use.

This region is also characterized as a drought landscape. Although drought is a natural seasonal phenomenon in Mediterranean regions like California, recent years have shown an increase in more extreme dry and hot years attributed to climate change (Diffenbaugh *et al* 2015,Mann and Gleick 2015). The longest duration of drought in California lasted 376 weeks from December 2011 to March 2019, with the most intense period of drought in July 2014 affecting >50% of California land (US Drought Portal 2019).

In this Central Coast region, we studied 19 urban allotment community gardens serving approximately 1,000 community gardeners, most of which are overseen by the city government, where individual gardeners lease single allotment plots to cultivate plants as they choose under rules of the garden management. The community gardens in the study were selected based on the criteria that they were allotment gardens in which individuals or households manage their own plots. Some gardens also have common areas including orchards and herb gardens that all gardeners collectively manage. The gardens were established up to 43 years ago (from 1977 onward), are from 404 m^2 to 12,141 m^2 in size, and have between 20 and 200 allotment plots (ten to 56 m^2 in size). An annual registration fee is around \$50 to \$200 USD per year depending on the garden, and includes a water fee, an administrative fee, and materials fee. A majority of these gardens have participated in urban agriculture research for the past five years, specifically around climate mitigation and water conservation (see Lin and Egerer 2020). This study took place after the drought, from June to August 2019, a time of year characterized by little rainfall and periodic heat waves (Rippey 2017). Though heavy winter rains in 2018/2019 alleviated drought impacts from the prior years, some garden bylaws had influenced or required the garden management to impose watering restrictions, limiting the number of days in the week and time of day that gardeners were allowed to water. After the drought, some gardens no longer had watering restrictions, while some gardens maintained their water restrictions or regulations/rules.

2.2. Survey questionnaire

We designed and distributed a survey questionnaire to gardeners in all gardens to collect information about gardener characteristics, levels of environmental concern, planting motivations, drought influences on gardening behaviors, and specific reported gardening behaviors (practices) before (‘$\mathbf{t_0}$’), during (‘$\mathbf{t_1}$’), and after (‘$\mathbf{t_2}$’) the most recent drought. The survey included multiple choice questions, 5-point Likert scale statements, and open-ended questions. We provided the survey to all gardeners in English, Spanish, and Mandarin languages.

To collect information on environmental concern, a series of four 5-point Likert questions asked gardeners to indicate how strongly they agree with statements on concern about the impact of drought and heat on their crop plants (vegetables, herbs, flowers, etc) growing in their garden and on water access (tables 1 and 2, supplementary information is available online at stacks.iop.org/ERC/2/041004/mmedia). Responses to each of the questions were averaged for one score, where a higher average score indicates stronger concern. To assess if and how gardeners perceive climate change, we additionally asked gardeners three questions about whether they agree (1) the climate is changing, (2) droughts are getting worse and (3) water is becoming scarcer.

To collect information on gardener motivations around plant selection and motivation to garden, first, a series of six 5-point Likert questions asked gardeners to indicate how important certain plant species attributes are, including: provision of food/usable products, beauty/aesthetics, cultural meaning, low maintenance, habitat and food for animals, and water use/needs. Second, we asked gardeners to identify their main motivation to garden (multiple-choice; e.g., food, recreation, health).

To collect information on behavior change, first, a series of a series of four 5-point Likert questions asked gardeners to indicate how strongly they agree with statements about the influence of drought and heat on their watering and planting practices. Responses to each of the questions were averaged for one score, where a higher average score indicates stronger influence of drought and heat on gardening behaviors. Second, seven water conservation-based practices important in urban agriculture (Wortman and Lovell 2013) were used to ask gardeners what watering practices changed during and after drought, indicating which practices they used at t_0, t_1, or t_2. Practices included: watering in the early morning or late evening; adding mulch or compost to improve soil’s ability to hold water; choosing the right plants and planting the right amount at the right time; adjusting water application to plant lifecycle; weed management; and hydrating root zone when watering. One open-ended question asked gardeners to elaborate on other changes that they have made not covered by the presented practices. Together these questions resulted in reported practices adopted at t_1, and reported practices maintained at t_2. We then calculated whether each reported behavior was adopted and/or retained for each gardener at each time point transition (i.e. t_0 to t_1; t_1 to t_2). For example, if a gardener reported that they did not add mulch to improve soil’s ability to hold water prior to the drought (t_0) and reported that they did during the drought (t_1), they received a ‘1’ for t_1; if a practice was reverted, they received a ‘−1’; if a practice was kept, they

Table 1. Water conservation-based practices adopted, retained, or reverted by gardeners during the drought and after the drought. Data presented as the percentage of total respondents for each practice (%), where values where calculated by comparing the use of a practice during drought in relation to before drought (a) and from during drought to after drought (b).

Water conservation practices reported	Add compost to improve soil's ability to hold water	Add mulch to improve soil's ability to hold water	Garden planning to choose the right plants and planting the right amount at the right time	Ensure root zone is hydrated when watering	Water in early morning or late evening	Adjust water application timing to the lifecycle of the plants	Weed management
(a) During drought (t_1)							
Adopt	21.74	21.74	16.30	21.74	32.61	19.57	15.22
Retain	56.52	59.78	66.30	54.35	52.17	63.04	60.87
Revert	21.74	18.48	17.39	23.91	15.22	17.39	23.91
(b) After drought (t_2)							
Adopt	18.48	11.96	19.57	21.74	13.04	17.39	23.91
Retain	69.57	65.22	69.57	69.57	58.70	72.83	69.57
Revert	11.96	22.83	10.87	8.70	28.26	9.78	6.52

received a '0'. We did this across all behaviors for t_1 and t_2, resulting in a combination of numbers to statistically analyze for each gardener.

To collect information on gardener and garden characteristics, one question asked gardeners about gardening experience (open; the number of years gardening) and another question asked to indicate a level of formal education (multiple choice). A series of six 5-point Likert questions asked gardeners to indicate how strongly they agree with statements on their relationship to nature following the 6-question Nature Relatedness Scale (Nisbet and Zelenski 2013), a scale that aims to assess individual differences in the affective, cognitive, and experiential relationship individuals have with the natural world (Nisbet *et al* 2009). The scale correlates with environmental attitudes and self-reported behavior and appears to be relatively stable over time and across situations. We use the term 'nature relatedness' to refer broadly to connectedness and relationships with nature. Responses to each of the six questions were scored and averaged according to Nisbet *et al* (2009), where a higher average score indicates a stronger connection to nature. Last, we asked whether the garden had water use policies and what particular policies were in place (multiple-choice with open statement option). Because open-ended statements illuminated policies that were not encapsulated in the multiple-choices, we ranked responses in order of what we perceived as increasing strictness. Gardeners without rules at their gardeners received a '0'; gardeners that reported some general policies in the open-ended statement such as 'no overhead watering' received a '1'; and gardeners that had strict rules in place on watering days and/or timing received a '2'. This provides a course method in which to understand general patterns of change; however, we recognize that there may be some variation to the extent in which individuals decided to revert, maintain, or adopt new management systems into their plots.

We worked with community garden managers to distribute survey questionnaires via an online platform to all gardeners in English, Spanish and Mandarin languages. We aimed to get as many gardeners as possible per garden, recognizing that our aim to reach all ~1000 gardeners was limited by computer access by some elderly gardeners and time constraints.

2.3. Analysis

We received 92 completed surveys to analyze at the gardener unit of analysis (88 in English, three in Mandarin, and one in Spanish). We performed three statistical analyses. First, we used a structural equation model (SEM) composed of eleven generalized linear models (GLMs) to determine whether gardener characteristics and garden policy influence gardening behavior, and changes in practices in response to drought (t_1) and after drought (t_2). We leveraged the SEM approach in order to visualize and statistically test for the relative effect of multiple correlated explanatory variables, and their potential interrelations, on a given response variable along a causal path (Grace 2005). This is a common interdisciplinary approach in environmental research to predict how, for example, social characteristics influence environmental behaviors including water use (e.g.(Syme *et al* 2004)). The series of GLMs in the SEM specifically tested: (1) how gardener characteristics (experience, nature relatedness, education level) and water policy influence environmental concern and planting motivations; and (2) how gardener characteristics, water policy, environmental concern and motivation influence gardening behaviors, the adoption of practices at t_1 and retention of practices at t_2. We performed SEM analyses in the R package *piecewiseSEM* (Lefcheck 2016).

Second, we used five Kruskal-Wallis non-parametric analyses of variance tests to analyze for significant differences in the seven practices used before drought, during drought, after drought, adopted during drought, and retained after drought. Kruskal-Wallis tests are useful to analyze an independent variable with two or more levels or independent groups, and where linear assumptions are not met due to unequal variances among groups. We then used a Mann-Whitney post-hoc test to determine which practices significantly differ from one another (significance tested at $\alpha = 0.05$).

Third, to associate changes in practices at t_1 and t_2 with garden and gardener characteristics, we used non-metric multidimensional scaling (NMDS) ordination based on Bray-Curtis distance measures and 999 permutations in the R package *vegan* (Oksanen *et al* 2019). We used NMDS ordination combined with the envfit function in *vegan* to visually compare the similarity or dissimilarity in the combination of ways that gardeners changed their practices over time, and how they were influenced by gardener characteristics (experience, nature relatedness, education level), drought concern, planting motivations, and water policy. We analyzed (1) reported influences on planting and watering behaviors, (2) practice adoption at t_1, and (3) practice retention at t_2. The NMDS model was used to determine gradients of maximum variation in the combination of reported behavior changes by respondent characteristics. We then tested for significant differences in the combinations of responses using Analysis of Dissimilarly tests (ADONIS) and permutations with significance tested at $\alpha = 0.05$.

All statistical analyses were performed in R v. 3. 6. 0 (R Development Core Team 2016).

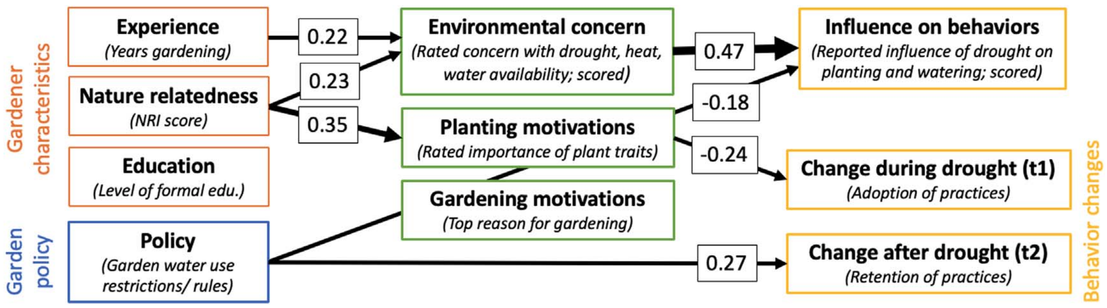

Figure 1. Structural equation model (SEM) of relationships/pathways to behavior change, as an indicator of climate change adaptation throughout drought periods. Pathways to behavior changes (yellow boxes) hypothesized to be predicted by gardener characteristics (orange boxes) which affect gardener environmental concern and motivation for plant selection (green boxes), and by the policy environment around water use in the garden (blue box). Numbers (black boxes) indicate standardized effect sizes in the SEM, where positive numbers indicate positive relationship and negative numbers indicate a negative relationship. Larger numbers indicate a stronger relationship between the variables. Arrows with a significant effect are shown for visualization purposes, with arrow thickness a representation of effect size and p-value. Unexplained variance is not shown for simplicity. Analysis performed using 'psem' function in the R package *piecewiseSEM* (Lefcheck 2016). See supplementary table 1 for questions determining environmental concern score and influence of drought on planting and watering behavior score.

3. Results

3.1. Description of gardener characteristics, their associations, and garden policy

The gardeners surveyed represent a range of gardening experience, from three months to 71 years gardening (mean 27 years), and in level of education, from a high school education (2.2%) to an associate degree (7.6%), a Bachelor's degree (30.4%) or doctoral degree (44.6%). The gardeners are growing a range of plants in their gardens (table 2, supplementary information). While many gardeners are motivated to grow food (29.3%), gardeners are also motivated by other reasons including recreation (21.7%), psychological benefits (17.4%), and physical health benefits (11.9%). Furthermore, gardeners vary in their connection to nature, from 1.3 to 5 (mean 4) on the nature relatedness scale. Most surveyed gardeners strongly agreed that the climate is changing, droughts are getting worse, and that water is a scarce resource (figure 1, supplementary information). Furthermore, most gardeners reported strong environmental concern regarding how drought would affect water availability and access (cost) in their community gardens, and the impact of drought and heat on their gardens. Many gardeners indicated that drought and weather patterns influence their water use, but there was overall less agreement that drought and weather influence the plant species selection (Supplementary Information).

Most gardeners had some form of water use rules/policies at their gardens (~55%) before and after drought, and these policies ranged in their strictness. Common water policies in place at gardens included controlling the days of week that gardeners can water and at what time of day, and how gardeners can water, specifically the watering equipment (e.g. drip irrigation, shut-off nozzles). Gardeners in one garden reported that their system uses recycled water, and though water use amount is not limited, 'there are rules (and training required) about using it.' This unique recycled water system was well described by one gardener: 'Our garden is plumbed to the largest recycled water system in Northern California and is 30%–50% blended with reverse osmosis water produced by the County's water wholesaler. This is the only community garden in California that I know of permitted to use recycled water. The system is designed to deliver twice the current peak summer usage, so water users have not been rationed, but overall water use did decline during the State-ordered drought.' Indeed, of the 16 surveyed gardeners in this garden (17.4% of all surveys), six gardeners specifically reported that the recycled water system's associated rules influence their watering. Only one gardener across all surveys reported that the garden does not allow crops that require high water usage.

3.2. Gardener characteristics and garden policy influence gardeners' behavior

Gardener characteristics along with garden water policy influenced gardening behaviors around planting and watering (figure 1). Both the number of years gardening and nature relatedness positively related to environmental concern. Gardeners with more experience and higher nature relatedness scores are more concerned about the effects of drought and increasing heat events on their gardens, and they are more concerned that increasing drought will cause water scarcity and increase water costs in their gardens. These gardeners are overall more influenced by these changes in their planting and watering decisions. Furthermore, these gardeners are more likely to change their gardening behaviors (watering, planting) during extreme events and more likely to shift their behaviors with changing conditions. Garden rules around water use negatively related to reported

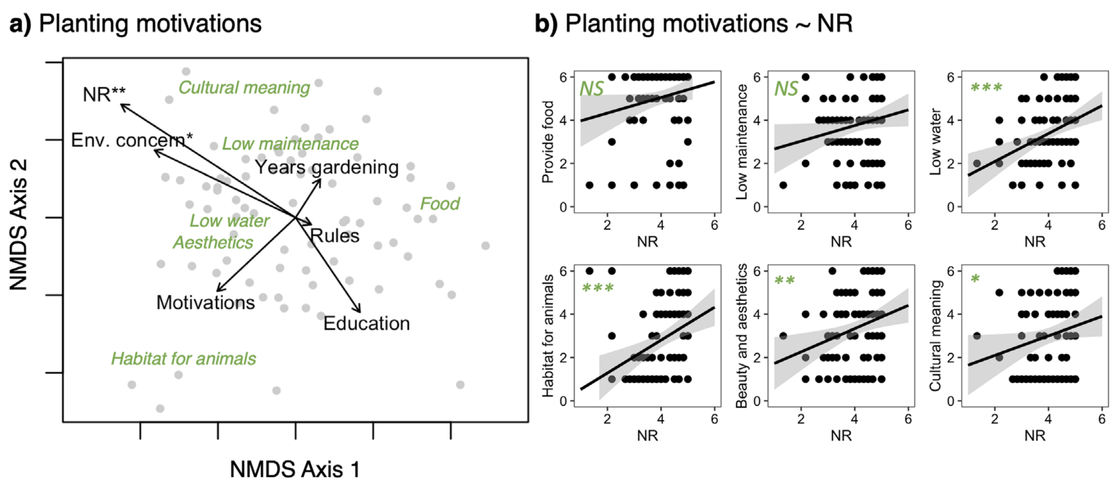

Figure 2. (a) NMDS ordination of the gardener responses to the series of questions around plant selection using non-metric multidimensional scaling. Each gray point represents a gardener. In green italics are the plant characteristics, and their spatial relation to one another based on the Bray-Curtis distance among the responses. In black are the gardener (years gardening, environmental (Eenv) concern, education, nature relatedness (NR), motivations) and garden (rules) characteristics as environmental gradients, tested as significant drivers of responses using analysis of dissimilarity (ADONIS) with significance at $\alpha = 0.05$. Plots created using the 'ordiplot' function in the R package *vegan* (Oksanen *et al* 2019). (b) The direct correlations between nature relatedness (NR)—a significant driver in the way in which people are motivated to plant plants with specific plant attributes. * indicate significant regressions ($^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$) in both (a) and (b).

influence of drought on planting and watering, indicating that gardeners at gardens where there were rules governing their behavior (e.g. days of week or time they can water) were less likely to change their watering or planting practices).

Nature relatedness significantly associated with gardeners' plant selection (figures 1, 2). Gardeners with higher nature relatedness scores are motivated to select plants with low water needs, provide habitat for biodiversity, and are aesthetically pleasing (figure 2). Whether these plants provide food or are low maintenance are not significantly important to these gardeners.

Environmental concern and nature relatedness significantly influence how gardeners change behaviors in response to drought (figure 3).

3.3. Changes in practices during drought (t_1) and after drought (t_2) in relation to gardening characteristics and garden policy

3.3.1. During drought (t_1)

Across all survey respondents, there were no significant differences in specific practices used before drought (Kruskal–Wallis: $X^2 = 5.9$, df $= 6$, $p = 0.43$), during drought ($X^2 = 5.9$, df $= 6$, $p = 0.43$), nor in practice adoption during drought ($X^2 = 8.68$, df $= 6$, $p = 0.19$). A majority of gardeners are already using conservation-based practices, and these gardeners tend to retain them throughout time (table 1). More gardeners adopted changes in water timing at t_1 (i.e. watered in the early morning or late evening), while fewer adopted weed management practices or changing their planting schedules. Furthermore, planting motivations influenced practice adoption at t_1 (figure 1). Here, during drought, gardeners motivated by food production (planting plants that provision food) were less likely to adopt conservation-based practices.

3.3.2. After drought (t_2)

Many gardeners retained conservation-based practices after drought. However, there were differences in the practices used after drought ($X^2 = 21.82$, df $= 6$, $p = 0.001$), and in the specific practices adopted or retained after drought ($X^2 = 25.08$, df $= 6$, $p = 0.0003$). Watering time (in the early morning or evening) was the most frequently reported practice to be reverted at t_2 (compared to other practices, nearly three-fold). Gardeners still adopted certain practices at t_2, including weed management and focusing watering on the root zone. The SEM showed that garden rules positively related to practice retention at t_2. This may be reflected in table 1: the most frequently reported practice reverted at t_2 is water timing, a common (16%) reported water policy in these gardens.

Gardener characteristics influence the pattern in how gardeners changed practices at each timepoint transition (t_1, t_2) (figure 4). The number of years gardening and nature relatedness influenced how practices were adopted at t_1 (figure 4(a)). Gardening experience influenced how gardeners changed practices at t_2 (figure 4(b)). In particular it seems that gardeners with more experience (decades; 60% of gardeners) tended to retain practices at t_2, while those with less experience (three months to three years; 13%) tended to show overall much more

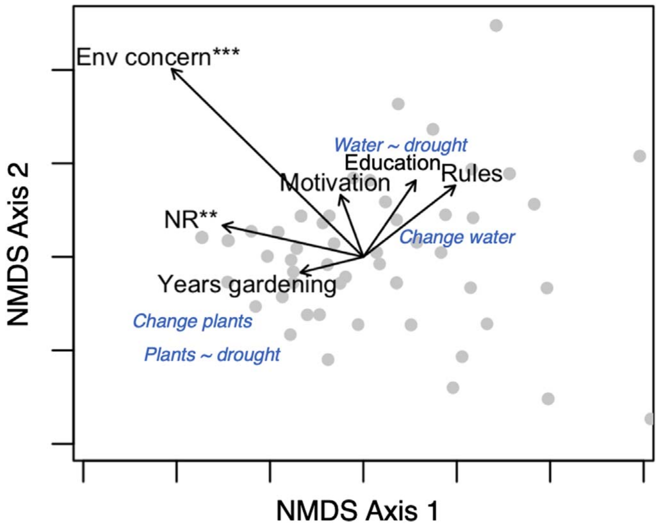

Figure 3. NMDS ordination of plotted reported influences of drought on planting and watering practices where each gray dot represents a gardener. In blue italic text are behaviors and their relation to one another based on the Bray-Curtis distance. In black are the gardener (years gardening, environmental (Env) concern, education, nature relatedness (NR), motivations) and garden (rules) characteristics as environmental gradients, tested as significant drivers of responses using analysis of dissimilarity (ADONIS) with significance at $\alpha = 0.05$. * indicate significant regressions ($^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$). Plots created using the 'ordiplot' function in the R package *vegan* (Oksanen *et al* 2019).

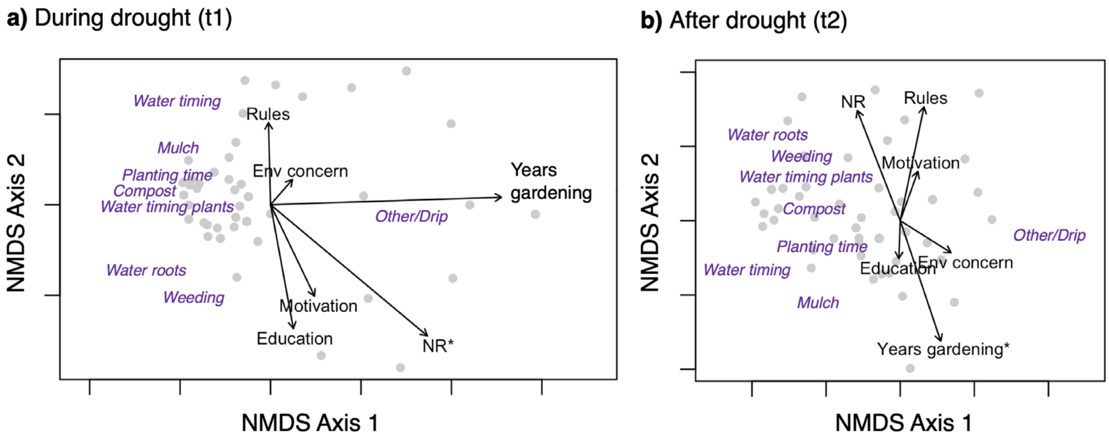

Figure 4. NMDS ordination plot of plotted reported changes in practices during drought (t_1) and after drought (t_2) where each gray dot represents a gardener. Plots show influence of drought on specific behaviors/practices adopted during drought (a), and specific behaviors retained after drought (b). In purple italic text are practices and their relation to one another based on the Bray-Curtis distance. In black text are gardener (years gardening, environmental (Env) concern, education, nature relatedness (NR), motivations) and garden (rules) characteristics as environmental gradients, tested as significant drivers of responses using analysis of dissimilarity (ADONIS) with significance at $\alpha = 0.05$. * indicate significant regressions ($^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$). Plots created using the 'ordiplot' function in R library vegan (Oksanen *et al* 2019).

variability in using practices at t_2 (or the combination of ways in which they are adopted). These 'novice' gardeners tended to adopt practices at t_2 not adopted at t_1 such as composting, changing their planting times, and watering at the roots of plants. In the open-ended responses, novice gardeners reported adopting technology including drip irrigation and water timers, whereas more experienced gardeners reported employing more knowledge- and time intensive practices that are revitalized practices or practices that they learned from previous experiences. Examples include succession planting, creating 'bowls' around plants, planting inside bottom-less buckets to focus watering, and watering deeply but infrequently. Reported by a gardener with the second longest experience: 'one rule of thumb with tomatoes who need water less than most gardeners use: If the tomato plant is droopy at night, only water if it is droopy the next morning.' Other experienced gardeners reported conservation composting and mulching: 'In the fall, I take my garbage barrels and collect leaves raked into piles in the street from the neighborhood to put huge layer on all my beds for the winter.'; and 'Sheet composting in the winter to enrich soil and discourage weeds.'

4. Discussion

A combination of individual experience and knowledge, nature relatedness and garden water use policy can influence behavioral change in watering and planting practices in response to weather extremes that are increasingly impacting urban agriculture. However, in this case study in urban community gardens in California, these factors influence and affect different types of behavioral change. We found that gardening experience tends to encourage more proactive and adaptive changes in practices to create more resilient garden plots, whereas policies ensure more reactive changes in watering behavior to the current conditions. This suggests that both policies as well as environmental knowledge, education and awareness are important to promote adaptation to climate change. We explore our main findings in the following discussion by highlighting three main pathways to behavioral change around planting and watering in urban agriculture.

4.1. Pathway 1: Nature relatedness and drought concern affect environmental management and behavior change

Literature has largely shown how demographics and experience shape people's connection to nature (Kaplan and Kaplan 1989, Kollmuss and Agyeman 2002, Lumber *et al* 2017), including in cities (Shanahan *et al* 2015, Lin *et al* 2017, Shanahan *et al* 2017). Work is also revealing how nature relatedness impacts environmental values, beliefs and attitudes (Wang *et al* 2019). We found that nature relatedness has a downstream influence on people's concerns about how weather extremes will affect their gardening—which in turn influences behaviors and affects pathways to changes in practices (figure 1). Furthermore, nature relatedness strongly influences the way that gardeners select the plant species that they grow: people with high nature relatedness are planting species with low water needs that provide habitat for biodiversity, and are aesthetically pleasing. High nature relatedness and high concern are leading to a different selection of plants that seems to encourage behavioral adaptation to changing conditions through changes in plant species selection. We see this as a very important behavior change. Most gardeners simply change their watering practices—which we may consider a reactive response to climate change extremes on the short term. In contrast, changes in plant selection towards plants with, for example lower water needs may be considered a proactive adaptation to climate change that has the most promise to increase agroecosystem resiliency under climate change, though this may mean trade-offs in food production. Thus, while nature relatedness influences drought concern and behavior change, gardeners with low nature relatedness may need other types of motivation to change behavior. In these situations, watering rules and regulations can help maintain behavior changes through the drought and beyond the drought by encouraging gardeners to continue practicing water conservation behavior, which we now discuss in Pathway 2.

4.2. Pathway 2: Policy affects behavior change where concern is absent

Those with rules at their gardens as to what days and hours they could water reported changing their practices throughout the drought, and were more likely to retain these practices after the drought. This supports prior findings demonstrating the important role of institutional governance structures on water use in community-based urban agriculture under drought (Diekmann *et al* 2017, Egerer *et al* 2018). Rules and regulations on water usage can shrink gardener water use by reducing the frequency of intensive watering, inspiring technological or infrastructural arrangements to improve watering efficiency, or by introducing a notion of shared norms around water where people are expected to use less by a social community (Seligman and Finegan 1990, Chappells *et al* 2011). For example, in the garden that uses recycled water, one gardener reported: 'Recycled water has its own rules and we do try and conserve no matter the water supply.' Here, community expectations and governance systems instated to conserve water may reduce water use through 'good citizenship' notions (Holmes 1999). Interestingly, despite having high nature relatedness and drought concern, some of these gardeners did revert their conservation behaviors or practices during and after the drought. This means that even with high nature relatedness and high concern, rules may be needed to enforce proactive change and maintaining practices, and are important for maintaining conservation behaviors during times of change. Rules may 'nudge' people to adopt more sustainable conservation-based practices, adopt new ways of gardening, and/or may build social norms around conservation practices within a gardening community. However, we found that gardeners motivated by food production are more likely to not adopt or to revert their conservation-based practices during drought events. For example, one gardener in this category stated: 'no changes… I prefer certain plants and grow from seed collected over the years.' Other studies have also shown that gardeners motivated by food production will find ways to work around rules to protect their garden's productivity (Domene and Saurí 2006, Garcia *et al* 2015). Thus, water policies and rules are important for directly reducing water access and indirectly instilling notions of environmental norms, and this may be especially important where drought concern is absent. Yet rules will need to be mindful of and negotiate food production desires of gardeners.

4.3. Pathway 3: Experience shapes pathways towards behavior adoption and retention

People's experience shapes the pathways though which people are adapting to climate change from season to season. In our study, years gardening was highly significant in the results, and it shows that the gardeners with more experience have higher drought concern, and adopt different types of water conservation practices than novice gardeners with fewer years of experience. Specifically, the practices that people use to drought-proof their gardens or prevent negative drought impacts on plants varied with experience. The gardeners with decades of gardening experience (60% of gardeners) tended to utilize knowledge intensive practices. In contrast, novice gardeners (12%) adopt technological practices for water use efficiency including drip systems and water meters. Thus, through experience from season to season, gardeners are learning how to adapt to climate change by altering their water use behavior, plant care, and soil management practices (Avolio *et al* 2015, Egerer *et al* 2019b). In addition, though we did not ask gardener's their region of origin, experience with drought as a resident in drought prone areas is likely also important. Other studies in suburban households in the Mediterranean coast have shown that residents' geographical origin and length of residency predict people's water conservation behaviors (Garcia *et al* 2013). In this study, as one long-term gardener (70 years) that has consistently used conservation practices since before the drought stated: '…I'm a native Californian and am used to the normal weather cycles we have. Adaptation is the key.' Borrowing from cognitive and social psychology understandings (Perkins and Grotzer 1997, Bransford *et al* 2000), the 'adaptive expertise' of gardeners develops over time through observations and learning, eventually building skills and cognitive abilities to deal with new situations (Bialystok *et al* 2005), and ultimately the response capacity to change (Fazey *et al* 2005).

The finding that novice gardeners with few years of experience (from a couple of months to two years) adopted practices after the drought that they did not adopt or use during the drought such as composting, changing their planting times, and watering at the roots of plants could suggest a lag effect in how learning via experience is implemented in practice. New gardeners may simply need more time before the benefits (e.g. environmental, food production) of behavioral adaptation are realized, may not have experienced the full duration of the drought and its impacts on their garden, or may be overall benefiting from the experience or social-ecological memory of the gardening community. Indeed, urban gardens foster diverse types of learning by bringing individuals together to socially share skills and knowledge particularly around environmental management (Krasny and Tidball 2009, Barthel *et al* 2010). The social collaboration in resource management can empower gardeners to make management changes through their collective learning as a social network of both novice and expert gardeners (Okvat and Zautra 2011). In sum, social learning or passive adoption of practices through social norms in the garden community instilled over the years of drought may promote practice adoption and behavioral change even where experience is absent.

5. Conclusion

We conclude with three main points to guide future research in environmental management in urban agriculture. First, this work highlights that it is necessary to focus on influences on behavior and behavioral change to understand the complexity of environmental management. Furthermore, it is important to explore and identify both the social and environmental mechanisms that drive practice adoption and retention over time. This type of work will be more essential to undertake as weather patterns increasingly vary in extremes and unpredictability from season to season in the climate change era. Second, our work shows that nature relatedness has downstream impacts on environmental behavior, and potentially people's ability to cope with and adapt to climate change impacts. Thus, while most work focuses on the 'upstream' social-environmental factors driving peoples' nature connection, we encourage integrating measures of nature relatedness into formal analyses, and particularly so in urban environments where these relationships are changing in society in response to urban densification or greening. Third, this work furthers the idea that urban agricultural systems are complex urban social-ecological systems impacted by environmental change processes. Dynamic city policies in combination with knowledge, skills, and an environmental awareness are needed to promote and support proactive behavioral change and adaptation to create resilient systems under climate change.

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